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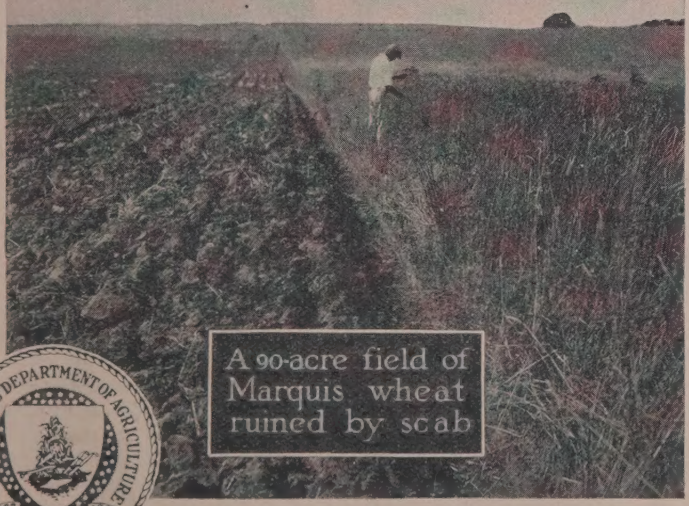
SCAB OF WHEAT AND BARLEY *and its control*



A 90-acre field of Marquis wheat ruined by scab

THE SCAB DISEASE greatly reduces the yields, lowers the quality, and lessens the value of wheat and barley in the Central and Eastern States. It also attacks rye, oats, and corn though less generally than wheat and barley.

When scabbed grain is fed to hogs it acts as an emetic causing vomiting. The hogs then refuse to eat such grain so that appreciably scabbed grain is wholly unsuitable for hog feed. Horses refuse to eat scabbed grain, but cattle, sheep, and chickens eat it with no ill effects. Scabbed grain is objectionable for human consumption.

Scabbed heads bleach to a straw color in wheat and darken in barley before the grain ripens. The scabbed kernels are shriveled, rough, and scabby, and frequently are covered by a grayish-white to carmine-red mass of mold.

Scabbed kernels used for seed germinate poorly, and the seedlings are weakened or blighted.

The fungus that causes scab lives over winter and forms spores on crop residues such as old cornstalks, straw, and stubble. These spores are carried by the wind to the developing heads of wheat and barley and infect them when they are in the flowering or bloom stage.

Moist, warm weather when the grain is flowering or is in the milk stage favors the development of scab. Scab cannot be entirely prevented by any known treatment that is practicable, but infection can be greatly reduced by the following measures:

(1) Plow under cornstalks, grain straw, and stubble completely and clean up the crop residues; do not sow grain among cornstalks.

(2) Using clean, plump seed of adapted varieties.

(3) Treating the seed with a good organic mercury fungicide.

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SCAB OF WHEAT AND BARLEY AND ITS CONTROL[1]

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SCAB, or fusarium blight, is a disease of wheat, barley, rye, and oats caused chiefly by a minute fungus parasite known by the Latin name *Gibberella saubinetii* (Mont.) Sacc. In 1919 it was estimated that losses of wheat alone, caused by this disease, amounted to about 80 million bushels. The disease was destructive again in 1928 and 1935, particularly to spring wheat and spring barley. Damage has been heavy in local areas, especially in Illinois, Iowa, southern Wisconsin, southern Minnesota, and southeastern South Dakota, and in Maryland, Virginia, and North Carolina in several other seasons.

The disease attacks the heads and seedlings of the small grains. It is most conspicuous and does the most damage when it attacks the heads. Usually individual spikelets only are attacked, but with favorable conditions the entire head or large parts of it in wheat, rye, and barley may be infected. The infected portions are discolored and often are characterized by a distinctly pinkish color due to the masses of spores that develop.

Infected seedlings are stunted or killed. Damage in the seedling stage often escapes notice, or is attributed to poor seed and unfavorable weather at the time of and following seeding.

The fungus also attacks the seedlings, stalks, and ears of corn. In some years it causes damage as an ear rot of corn. Much of the infection in the small grains comes from the scab fungus living over winter on diseased crop residues, especially cornstalks.

The prevalence of scab on the grain heads in any year depends, first, on an abundance of spores that have developed on the residues from the previous crop, that is, on stubble, straw, and cornstalks; and, secondly, on favorable weather conditions at heading or flowering. The spores may be carried considerable distances by wind, but ordinarily the most severe infection occurs on fields in which the crop residue was not plowed under.

[1] Cooperative investigations of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, and the Wisconsin Agricultural Experiment Station.

OCCURRENCE AND LOSSES FROM SCAB

The scab disease occurs in several of the humid wheat- and barley-producing areas of the world. In the United States it occurs from the Mississippi Valley eastward in greater or less abundance every year, and scarcely or not at all in the semiarid plains and intermountain regions. Along the northern border of the United States temperature relations are generally less favorable for the development of scab than in the central areas. During wet seasons the disease often extends westward into the drier prairie regions. The general distribution of the disease on wheat and on barley and the estimated percentage losses for the 10-year period 1928 to 1937 are shown in figures 1 and 2

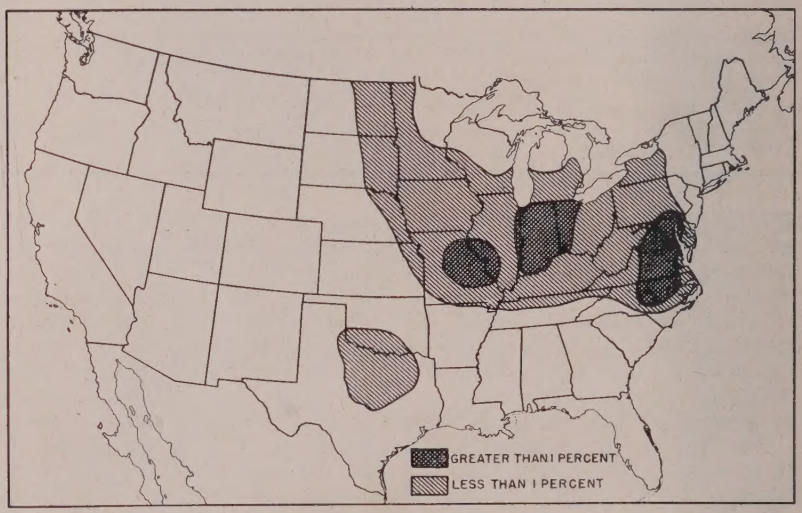

FIGURE 1.—Approximate distribution of loss of wheat from scab for the 10-year period 1928–37, based on estimates by the Division of Mycology and Disease Survey, Bureau of Plant Industry, Crop Losses from Plant Diseases, and annual scab surveys. Double shading indicates areas in which an average of more than 1 percent loss occurs annually; light shading, less than 1 percent.

Losses in wheat are greatest in the soft winter wheat area. Losses occur throughout the eastern half of the United States except in the extreme Southern States. The three heavily shaded areas centering in Missouri, Indiana, and Virginia show where estimated damage is above 1 percent annually. The average estimated annual loss, calculated in bushels of wheat, for the 10-year period is given in figure 3. Owing to the greater wheat production in Missouri, Illinois, Indiana, and Maryland, there is a greater total loss in bushels in these States that produce a large proportion of the soft winter wheat crop. Two years of very high scab damage, 1928 and 1935, are included in these averages.

Losses in barley are highest in the more humid and southern portions of the spring barley area. Damage throughout the area was high in 1928 and 1935 and there were local losses in every year except the drought years of 1934 and 1936. The average estimated annual loss, calculated in bushels of barley, is given in figure 4. As would be

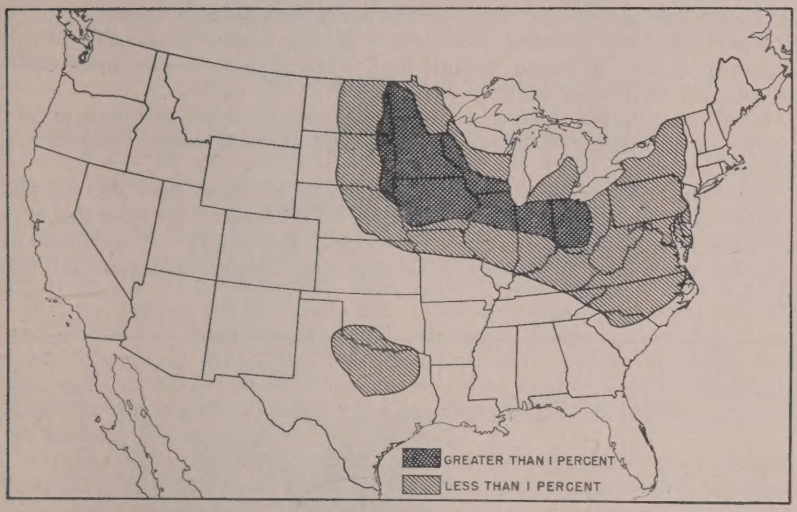

FIGURE 2.—Approximate distribution of loss of barley from scab for the 10-year period 1928–37, based on estimates by the Division of Mycology and Disease Survey, Bureau of Plant Industry, Crop Losses from Plant Diseases, and annual scab surveys. Double shading indicates areas in which an average of more than 1 percent loss occurs annually; light shading, less than 1 percent.

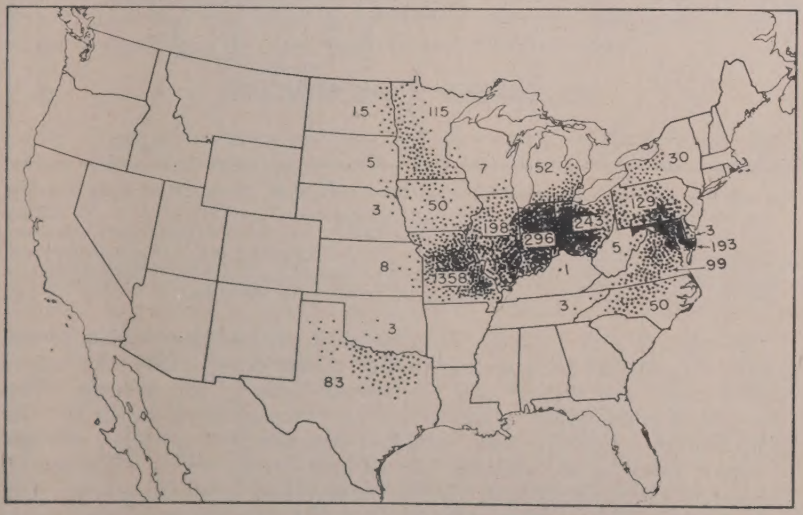

FIGURE 3.—Estimated average annual loss in bushels of wheat due to scab for the 10-year period 1928–37, based on estimates by the Division of Mycology and Disease Survey, Bureau of Plant Industry, Crop Losses from Plant Diseases; Agricultural Marketing Service, United States Department of Agriculture; and annual scab surveys. Each dot equals a thousand-bushel loss. Figures indicate the average annual loss in thousands of bushels for each State.

expected, the major loss occurs in the six most important spring barley States. In years such as 1928, when spring barley was used for replanting fields in which wheat had winterkilled, losses from scab frequently were very high.

Similar estimates of losses of corn, oats, and rye have not been given. Losses in corn and rye are occasionally high in local areas. In general, losses in oats are low.

Scab not only causes serious reductions in yield but also in the quality and feeding value of the grain. The fungus invades the kernels and frequently causes them to be light and chaffy. This invasion retards or stops the storage of starch and other substances in the kernel.

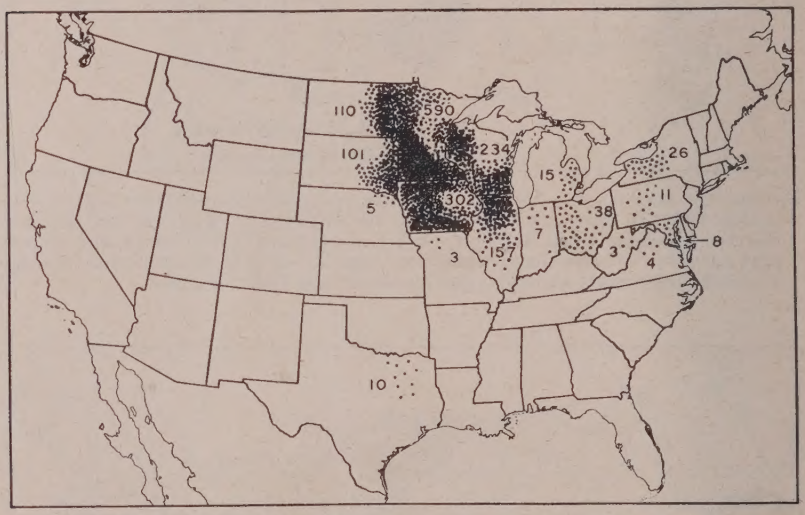

FIGURE 4.—Estimated average annual loss in bushels of barley due to scab for the 10-year period 1928–37, based on estimates by the Division of Mycology and Disease Survey, Bureau of Plant Industry, Crop Losses from Plant Diseases; Agricultural Marketing Service, United States Department of Agriculture; and annual scab surveys. Each dot equals a thousand-bushel loss. Figures indicate the average annual loss in thousands of bushels for each State.

The scab infection causes changes in chemical composition of the grain. In addition to retarding storage of starch especially, the fungus breaks down and partly uses the stored foods of the kernels. The byproducts accumulate in the kernel and remain after maturity. As compared with healthy grain, scabbed samples have a higher content of sugar, fatty acids, and soluble nitrogen compounds. The starch content is lower, and crude fiber is higher than in sound grain. The growth of the fungus in association with the developing kernel results in the accumulation of substances that cause vomiting when eaten by pigs and human beings.

Scabbed wheat and barley are discounted heavily when sold on the market for industrial uses or for feed. The Official Grain Standards of the United States require the designation "blighted barley" to be

added to, and made a part of, the grade designation when more than 4 percent by weight of scabbed- or blight-damaged barley occurs in the grain.

USE OF SCABBED GRAIN FOR FEED

Cattle, sheep, or chickens can be fed scabbed grain and not be affected by the substances formed in the diseased kernels. Feeding experiments have shown that these animals eat scabbed grain and make gains equivalent to those made with clean grain when the ration is supplemented to compensate for the lighter weight and greater chaffiness of the scabbed grain. It is advisable, therefore, to use scabbed grain on the farm for feeding these classes of livestock rather than to sell it on the market at a discount. This is especially true with barley, as the scabbed kernels cannot be separated readily from the sound grain. Scabbed wheat can be removed from sound grain with a fanning mill or other grading machines. Frequently it is profitable to separate the plump wheat for the market and use the scabbed wheat for feed on the farm.

Grain containing any quantity of infected kernels is not a suitable feed for pigs. It causes vomiting and subsequent refusal of the feed. Corn silage spoiled by the same fungus also affects pigs the same way. To determine whether grain has sufficient scab infection to make it objectionable for pig feed is to feed it to the pigs and then watch for vomiting and refusal to eat the grain.

Horses will not eat badly scabbed grain or grain containing appreciable amounts of scab-infected kernels. Scabbed grain is objectionable for human foods or food products. Since scab-infected wheat or rye kernels can be removed by proper cleaning equipment, scab in these grains is not so objectionable as in barley.

DESCRIPTION OF THE DISEASE

On small grains the scab disease occurs on the heads as head blight, often referred to simply as scab, and on the seedlings as a seedling blight that injures or kills the young plants.

HEAD BLIGHT

The head blight or scab becomes evident during the period from flowering to the maturity of the crop. The symptoms of the disease are similar, in general, on all the small grains. Some or all of the spikelets lose their green color, die, and turn straw-colored (fig. 5). Barley kernels frequently turn brown, especially toward the base of the infected spikelets (fig. 6). A salmon-pink or reddish-colored fluffy, dustlike growth of mold (called mycelium) frequently but not always is evident on the hulls or chaff and at the base of the spikelets. The extent of the spread of the disease in the head depends largely upon climatic conditions. Often isolated single spikelets only are infected. If continued wet weather prevails early in the blossoming period, the entire head may be overrun. Frequently the rachis, or central stem, of the head may be killed and the kernels in the upper part of the head become shrunken as a result, even though the upper part is not infected.

Scabbed kernels are badly shrunken and are conspicuous by their changed surface texture and color. In wheat the scabbed grains are

wrinkled and have a rough, flaky, or scabby surface and a pale-gray or whitish to salmon-pink or reddish color (fig. 7). In rye the manifestations of the disease are similar to those in wheat, except that the

FIGURE 5.—The scab may kill only a single spikelet or part of the head (center), or the entire wheat head (right). Compare with the healthy head at the left.

slightly infected kernels are dark brown and the badly scabbed kernels are usually carmine red (fig. 8).

In barley and oats the disease is less conspicuous because the kernels are covered by the hulls. Infected barley hulls usually are dark-

colored or light brown, especially near their bases, and the faces of the kernels beneath the hulls have a characteristic dusty-gray color. Badly scabbed kernels are shrunken and frequently are overrun by the pink coating of mycelium or may be partly covered by scattered masses of round, black perithecia (spore cases of the perfect stage of the fungus). In many instances of late infection, the hulls show only the darkened basal discoloration and the roughened texture and gray

FIGURE 6.—The scab may kill and darken individual spikelets or the entire barley head (right). Pink masses of conidia and black perithecia develop on the blighted kernels during continued moist weather. Compare with the healthy, ripe head at the left.

color on the face of the grains. The kernels within, however, may show the grayish, scabby, and shriveled condition characteristic of the disease (figs. 9, 10). The hulls of infected oat kernels are a dirty-grayish color, roughened, and frequently covered in part by the deep carmine-red mycelium or black perithecia. The infected hulls are not darkened, as in barley. The oat groats within the hulls also have the light, shriveled, scabby appearance characteristic of the disease on barley (figs. 11, 12).

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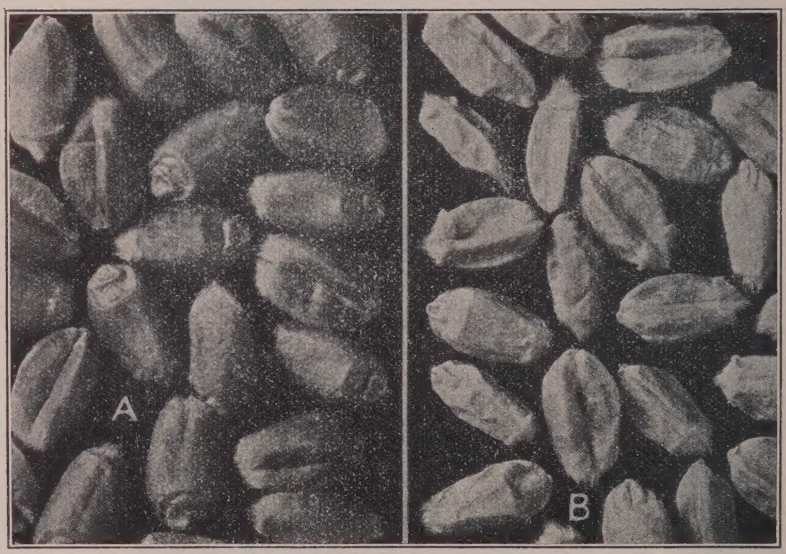

FIGURE 7.—Healthy kernels (*A*) and scabbed kernels (*B*) of Marquis wheat. Scabbed kernels are badly shriveled, gray or whitish in color, light in weight, and low in milling or feeding value.

FIGURE 8.—Scabbed kernels of Rosen rye. The badly infected kernels (*A*) are colored with a white to pink flaky growth of the fungus. The moderately infected kernels (*B*) are dark-colored and wrinkled.

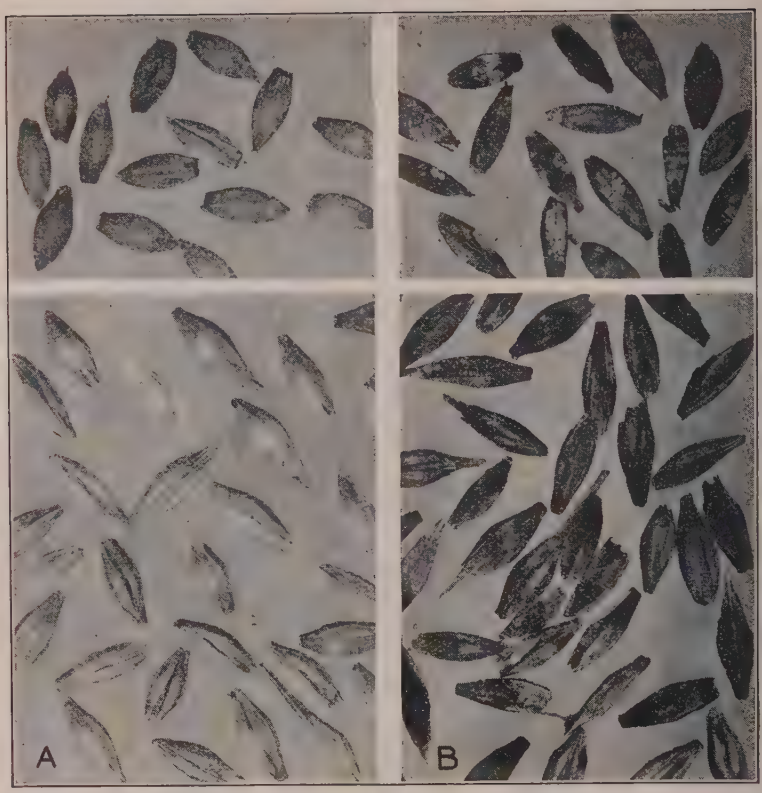

FIGURE 9.—Healthy (*A*) and scabbed (*B*) kernels of Oderbrucker barley. (Kernels with hulls removed, above.) The scabbed kernels are light brown, with a dusty-gray color over the face. The badly scabbed kernels are shrunken and frequently are covered by the pink mycelium and conidial mass or the black perithecia. The kernels, with the hulls removed, are grayish white or pink and shriveled.

FIGURE 10.—Scabbed kernels of Oderbrucker barley, showing the range from plump but darkened (*B*) to gray and shriveled (*A*) kernels covered by a mass of spores of the scab parasite.

FIGURE 11.—Healthy kernels (*A*) and scabbed kernels (*B*) of Kherson oats. (Kernels with hulls removed, above.) The scabbed kernels are dirty gray to deep carmine red. Frequently they are still enclosed in the outer chaff, bearing the round, black perithecia. The grain itself (above) is shriveled, rough, gray to pink in color, and of poor quality and low feeding value.

The scabbed, threshed grain can be detected in most cases by the presence of discolored kernels. Grain carrying a high percentage of infection is light weight, is discolored, and has few or many pink or red kernels and still fewer kernels showing the scattered masses of black perithecia.

This same fungus causes an ear rot of corn, which usually occurs on the tip end of the ear. The pink to red mycelium is conspicuous over the rotted surface of the ear and around the embryo end of the rotted kernels. The damage to the corn kernels is essentially similar to that in the infected kernels of the small grains.

FIGURE 12.—Scabbed oat spikelets, showing the black perithecia on the outside of the outer glumes.

SEEDLING BLIGHT

Seedling blight occurs either when scabbed kernels are used as seed or when poor seed or unadapted varieties are sown in scab-infested soil. The fungus attacks the seedlings during and following germination. The young plants frequently are killed before emergence. Others are killed after emergence, especially before the plants reach the tillering stage (fig. 13). In either case a poor stand may result. Other seedlings are infected and injured but not killed, resulting in stunted plants that produce a low yield. The infected parts below ground show a light-brown to reddish-brown rot either partly or completely invading the seedling tissues. A similar but wide range of symptoms occurs in the seedling blight of wheat, barley, rye, oats, and corn.

FIGURE 13.—Seedling blight caused by the scab fungus. Some of the diseased wheat seedlings fail to push out of the soil (left), others come up but die in the first-leaf stage, while others develop into weak plants (center). Normal seedlings, of the same age, from clean seed (right). Clean and treat the seed, in order to control this seedling blight.

CAUSE OF THE DISEASE

The head blight (scab), as well as a seedling blight of the cereals and grasses, is caused by a widely-distributed, rot-producing fungus called *Gibberella saubinetii* (Mont.) Sacc. and more recently designated also as *G. zeae* (Schw.) Petch. One stage of the fungus is of the *Fusarium* group of fungi, and in the fusarial or conidial stage it is known also as *Fusarium graminearum* Schw. In a few instances, in some sections of the United States, other closely related fungi cause the same type of disease; in still other sections and in Europe the scab disease is caused principally by another closely related species, *F. culmorum* (W. Sm.) Sacc. In the central and eastern United States *G. saubinetii* is responsible for about 98 percent of the damage. This parasite has two spore stages the imperfect-spore stage, called the conidial stage, and the perfect stage, called the perithecial stage.

The pink to red surfaces of the scabbed kernels or heads are covered with mycelium and conidia. The round, black bodies scattered over the surface of the badly infected heads and later on old straw and especially on cornstalks are the perithecia (figs. 14, 15, 16). Within

FIGURE 14.—Blue-black perithecia or perfect stage of the scab fungus on part of a scabbed head of Turkey wheat (*A*) and of Oderbrucker barley (*B*). These spore cases contain the ascospores important in the spread of the disease. × 4 (approximately).

these perithecia the ascospores are formed. These are largely responsible for the widespread wind dissemination of the parasite from old cornstalks and other crop residues to the developing grain heads during the late spring or early summer. The plowing under of old cornstalks helps to prevent this abundant formation of ascospores as well as conidia.

FIGURE 15. Blue-black perithecia of the scab fungus on wheat straw left on the field after harvest. This material must be plowed under to help prevent spread of the fungus to the next season's grain crop.

LIFE HISTORY OF THE PARASITE

The life history of the scab fungus is rather complex. As stated previously, it grows not only on various crop plants and produces disease while they are growing, but it also lives on the straw, chaff, and cornstalks after the crop is harvested (figs. 15, 16). It grows commonly on cornstalks and straw left in a moist condition on the surface of the soil, and thus it is carried over winter. The ascospores mature during the spring if there is sufficient moisture, and are discharged during continued moist weather in the late spring and early summer. If they fall on moist material of almost any kind, such as old straw, cornstalks, or manure, they start to grow and soon produce immense numbers of conidia. The mycelium and conidia also may live over the winter on crop residues. Both the conidia and the ascospores are blown to the heads of grain crops, where they grow and infect the young kernel. Mycelium, conidia, and ascospores may be carried over on infected kernels and sown the following season to cause seedling blight when weather conditions are favorable. Seed infection is not directly responsible for head infection the following season.

WEATHER CONDITIONS FAVORING THE DISEASE

Since weather conditions influence the development of the crop plants and the scab fungus, both the head blight (scab) and the seedling-blight phases of the disease are also affected. The disease develops best in warm, moist weather.

FIGURE 16.—Blue-black perithecia on an old cornstalk (*A*) and corn stubble (*B*) taken from a wheatfield near Madison, Wis. Unless all of the cornstalks and stubble are completely plowed under, these spores will spread to wheat and barley plants during the summer and cause scab.

CONDITIONS FAVORING HEAD BLIGHT

Warm, rainy weather during the flowering period of the grain crop greatly favors the spread and development of scab. Dry weather prevents the germination of the spores and the growth of the fungus, but warm, muggy weather, with heavy dews or light rains, furnishes favorable conditions for the germination of the spores and the subsequent infection and growth of the fungus in the kernel. If these weather conditions prevail widely and extend over a period when any of the cereals is flowering or filling, a scab epidemic may occur and cause immense losses over large areas, as in 1919, 1928, and 1935. The destructiveness of scab differs from year to year chiefly because of differences in weather conditions. The disease is usually more serious where the plants lodge.

CONDITIONS FAVORING SEEDLING BLIGHT

The seedling blight develops chiefly from infected kernels and from the scab fungus growing on crop residues on the surface of the field. A warm, comparatively dry soil favors the development of the seedling blight on wheat, barley, rye, and oats, and a cold, dry soil aids the development of seedling blight on corn. Thus warm, dry conditions that are unfavorable to the early growth of small grains and cold, dry conditions unfavorable to corn seedlings favor the development of seedling blight in the respective crops.

FIGURE 17.— Enlarged view of a wheat spikelet, showing the anthers (*a*) on which the scab fungus usually begins to grow. Later the fungus progresses downward into the flower, there to produce a scabbed kernel. Such entire spikelets or portions of heads may become blighted.

CONTROL MEASURES

Scab is very difficult to control completely under the present methods of farming in the Corn Belt. There is usually an abundant development of the parasite on the large quantities of cornstalks and other crop residues left on the surface of the field after disking or poor plowing, and the spores spread over the grainfields every summer (figs. 15 and 16). Whenever moist, wet weather occurs during or following the flowering period of the grain crops, local or general scab epidemics are started (fig. 17). Obviously, cleaning up the crop residues or plowing this material under completely, together with proper crop rotation, and the use of adapted varieties and disease-free and treated seed will greatly reduce the losses. All of these methods are practicable

and can be applied under general farm conditions. Those methods applied to a local field may not be sufficient to control the disease if surrounding fields have an abundance of crop residue and weather conditions are favorable for the spread of the fungus spores.

ROTATIONS AND THE PLOWING UNDER OF CORNSTALKS

A survey made in 1919 of fields in seven States where scab was severe and in Wisconsin in 1928 revealed valuable information as to the distribution of scab and its occurrence with reference to the effect of the preceding crop. Some of the important data obtained in these surveys are given in table 1.

TABLE 1.—*Influence of the preceding crop on scab infection* [1]

State	Counties surveyed	Fields examined	Scabbed crop	Average percentage of scabbed heads after previous crop of—					
				Corn	Wheat	Rye	Oats	Clover	Timothy
	Number	*Number*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Illinois	2	23	Wheat	59	33		33	22	
Indiana	10	47	do	39	25	30	16	20	
Iowa	9	27	do	71	49		30		
Minnesota	4	20	do	66	58	50	45		5
Ohio	5	39	do	33	6		11	1	17
Tennessee	5	16	do	21	4	1		9	
Wisconsin	4	10	do	14			1	5	3
Do	10	12	do	58	10		2	Trace	
Do	10	64	Barley	17	7		2	Trace	

[1] Data from scab surveys.

The surveys indicated that infection was greater in every case on land in corn the preceding year. Wheat, rye, oats, clover, and timothy as preceding crops tended to reduce scab in descending order. The general practice in the Corn Belt area is to grow wheat or barley following corn. When this is done the cornstalks and stubble should be completely covered in plowing.

Surveys showed less scab in wheat and barley when cornstalks and stubble had been turned under. Growers in southern Wisconsin who sowed barley on poorly prepared cornland in 1928 suffered an average loss of about 17 percent of the crop; whereas those who sowed on land from which the corn had been removed and the stubble completely plowed under suffered less than 2 percent loss. In the same year in Iowa, Illinois, and Indiana the difference in the amount of loss was even greater. In certain years when scab infection was very severe, especially in Illinois and Iowa, local fields on land free from crop refuse were damaged by scab due to the abundance of spores from crop refuse on other fields in the area.

The principal damage done by scab in the northern portion of the Corn Belt has occurred where spring grains were sown on cornland on which stalks were left on the surface (fig. 18). In this area where fields are well plowed, as is practiced in the dairy sections where corn is put in the silo and in the corn borer clean-up area (fig. 19), small grains can be sown on cornland without great danger of losses from scab.

FIGURE 18.—Cornstalks on a field sown to winter wheat. The cornstalks were broken down with a drag, after which the field was disked or poorly plowed. Enough diseased cornstalks remain on the surface of the soil to develop an abundance of the scab fungus to infect the wheat crop very severely if there is rainy weather when the wheat is in blossom. The field should have been carefully plowed and the cornstalks completely covered. (See fig. 19.)

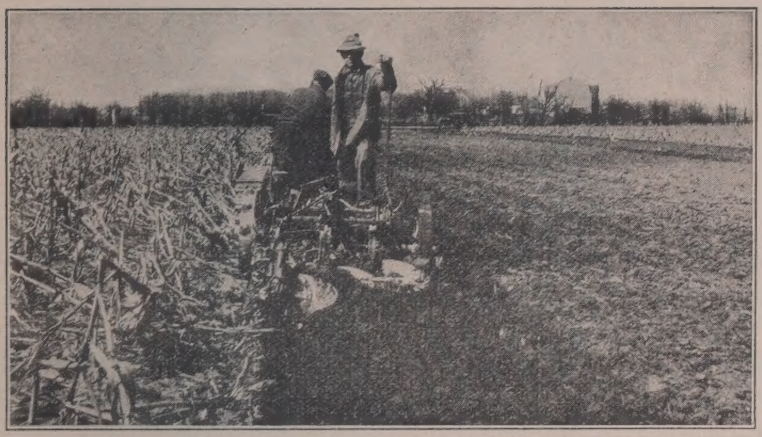

FIGURE 19.—Clean plowing will help control scab. It requires about 20 percent more power, as well as attention to adjustments, to turn under the stalks.

GOOD SEED, CLEANED AND TREATED

Seedling blight can be controlled by the proper selection of varieties and by the treatment of the seed. Varieties best adapted to the particular district and, if obtainable, seed free from scabbed kernels should be used. If it is necessary to use seed that contains scabbed kernels, the grain should be put through a fanning mill with a heavy wind blast to blow out the scabbed kernels and shriveled grain. The cleaned grain should then be treated with an efficient organic mercury dust disinfectant. In treating barley, it is advisable to use a dust treatment that will control certain smuts and the barley-stripe disease as well as scab. New Improved Ceresan is satisfactory for the control of these diseases. **New Improved Ceresan is a poison. In handling this dust and any seed treated with it, follow the precautions given on the container.**

The use of copper carbonate dust is not recommended for barley because it is less effective than New Improved Ceresan. Liquid formaldehyde, copper sulphate solutions, or hot-water treatments are not advisable, as they injure the seed and seedlings and thus tend to increase the damage from the seedling blight. Good seed should be used. The crop from well-cleaned seed, treated with any of the standard commercial mercury dusts and sown in a well-prepared seedbed, should suffer little seedling injury from scab.

USE OF ADAPTED VARIETIES

Scab-resistant varieties of wheat and barley are being sought by the State and Federal agricultural experiment stations, but with only partial success. Fairly resistant barley varieties have been found. These varieties, however, are not suitable for commercial production in most areas and, therefore, are useful for the most part only for breeding new, adapted scab-resistant varieties. Of the commercially grown six-rowed varieties of barley, Peatland is the most scab resistant. This variety is not adapted to much of the barley area. Chevron, Cross, and several other noncommercial varieties are scab resistant

and are being used in barley-breeding experiments. Svansota, a two-row barley, is among the more resistant varieties, but it also is not adapted to large areas. The hooded (beardless) barleys are very susceptible to scab and should be avoided where scab occurs abundantly.

Varieties of wheat and barley adapted to each area and acceptable for feed or industrial use should be grown until scab-resistant varieties have been developed, adequately tested, and distributed in the areas where scab occurs.

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